

# Exhibit 2

**UNITED STATES DISTRICT COURT  
SOUTHERN DISTRICT OF NEW YORK**

**In re: General Motors, LLC Ignition Switch Litigation**

**14-MD-2543 (JMF)**

**This Document Relates to:**

**MDL 2543 Economic Loss Proceeding**

**Expert Report of Joseph Fedullo**

**February 23, 2018**

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## **I. SCOPE OF WORK**

My name is Joseph S. Fedullo. I am currently the Director of Vehicle & Propulsion Systems Engineering for General Motors LLC. I was employed by General Motors Corporation from July 2000 to July 2009. I then became an employee of General Motors LLC. Throughout my tenure with GM Corp. and GM LLC, I have held various engineering positions.

In February 2014, I was asked to provide engineering support relating to the GM Ignition System Matter. This work involved, among other things, leading a team of GM engineers to develop unintended key rotation assessment testing for the vehicles subject to the investigations resulting in NHTSA Recall No. 14v047 (Delta), NHTSA Recall No. 14v355 (Impala), NHTSA Recall No. 14v394 (Cadillac CTS/SRX), NHTSA Recall No. 14v346 (Camaro) and NHTSA Recall No. 14v400 (Malibu). This work also involved assessing the effectiveness of the remedy implemented for those vehicles subject to these same recalls.

For this report, I was asked to evaluate from an engineering perspective the process that GM used to develop and conduct the unintended key rotation assessment tests and the recall remedy effectiveness assessment for the Delta Ignition Switch and Key Rotation Recalls. I was also asked to evaluate whether the remedies for each of these recalls sufficiently addressed the recall condition from an engineering standpoint.

I have reviewed and/or relied on the materials that are cited in this report, including but not limited to the documents and testimony listed in Appendix A. I have also relied on my experience in the automotive industry, my training as an engineer, and my experience providing engineering support to the GM ignition switch matter.

## **II. SUMMARY OF OPINIONS**

Based on the evidence that I have reviewed and the analyses that I have performed, I have reached the following opinions in this case to a reasonable degree of engineering certainty:

- GM applied sound engineering judgment to develop robustness to unintended key rotation assessment testing, which was reviewed and/or validated by independent third parties;
- GM applied sound engineering judgment in conducting the robustness to unintended key rotation assessment testing for vehicles subject to the investigations that resulted in each of these recalls;
- GM applied sound engineering judgment in developing and conducting the tests to assess the recall fix for each of these recalls;
- The remedies for each of these recalls sufficiently address the recall condition from an engineering standpoint.



### III. QUALIFICATIONS

I have over 17 years of experience working in the automotive industry in various engineering capacities, and worked for a year as an engineer at Bell Labs prior to that.<sup>1</sup> I am a named inventor on a U.S. patent and have several pending patent applications. I have received Design for Six Sigma (DFSS) Black Belt certification. I also was honored with GM's top technical honor, the Boss-Kettering award for developing the HiPerStrut suspension design. I have been an active Society of Automotive Engineers (SAE) member for 20 years, and I have co-authored and published a SAE technical paper surrounding a computational method for damper evaluations.

I received a full-tuition, merit-based scholarship to attend The Cooper Union for the Advancement of Science & Art in New York City where I earned a Bachelor of Engineering degree in Mechanical Engineering in May 1998. In 2000, I earned a Master of Engineering degree in Automotive Engineering from The University of Michigan in Ann Arbor. While at the University of Michigan, I was a Teaching Assistant for ME458 (Automotive Engineering), and ME 542 (Vehicle Dynamics).

### IV. RETENTION FOR THIS MATTER

I am currently a salaried employee of GM LLC, and therefore, I am not compensated directly for the time spent on this matter. The opinions I offer in this report have no bearing on my compensation or position with GM LLC.

I have testified once in deposition as an expert witness in the last 4 years: *The People of the State of California v. General Motors LLC*, No. 30-2014-00731038-CU-BT-CXC (Cal. Sup. Ct). I have also testified once at trial as an expert witness in the last 4 years: *Scheuer v. General Motors LLC*, 14-MDL-2543-JMF (S.D.N.Y.) (1/19/2016). I have provided a list of my publications in my resume attached as Appendix B.

### V. BACKGROUND

#### A. Engineering and Physics Terms and Principles

I will use some engineering and physics terms and principles throughout this report, of which I would like to explain a few in more detail.

Acceleration ( $a$ ) is the rate of change of velocity ( $v$ ). The value can be positive or negative depending upon the coordinate system utilized and if velocity is increasing or decreasing. Put in terms of an equation, acceleration is expressed as change in velocity divided by the change in time.  $a = dv/dt$

Force ( $F$ ) is a linear (straight line) push or pull. Newton's second law of motion states if a net force is acting on an object of constant mass, its acceleration is directly proportional to the magnitude of the net force and inversely proportional to the mass ( $m$ ) of the object. Put in terms

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<sup>1</sup>See my current resume attached as Appendix B.



of an equation, Newton's second law is expressed as force = mass times acceleration ( $F = m \times a$ ). The mass of an object is directly proportional to its weight.

Newton's second law ( $F = m \times a$ ) is pertinent to unintended key rotation. A force equal to the mass of the items attached to the key ring times the acceleration they experience is applied to the hole in the key head when the key ring accelerates the mass attached to it. To reduce the force that the items attached to the keyring generates, either their mass, or the acceleration they are subject to, must be reduced.

Torque (T), or moment, is analogous to force, but it is rotational. Similar to how force is a push or a pull, a torque is a twist. The applied torque around a pivot axis is equal to the portion of the applied force applied perpendicular to the pivot axis times the distance it is from the pivot axis. The perpendicular distance from the applied force to the pivot axis is called the moment arm or lever arm. Expressed in the form of an equation Torque is the product of force and the perpendicular distance from the force to the pivot axis ( $T = F \times d$ ).

Combining the Torque equation ( $T = F \times d$ ) and Newton's second law ( $F = m \times a$ ), the input torque into an ignition key due to inertial effects is equal to  $T = m \times a \times d$ . Because all three inputs are multiplied together, driving any one term to 0 drives the input torque to 0.

This principle was demonstrated physically in the vehicle tests with an ignition switch that had the detent plunger removed. With the detent plunger removed, the torque to rotate the switch was very low (1.3N\*cm). This switch was installed in a vehicle and then run through the 8 severe driving events described later in this report, however there was only an empty key ring with near 0 mass (0.007lb) attached to the ignition key. Although the accelerations were extreme and a slotted key head was used so the moment arm was the same as vehicles pre recall, unintended rotation never occurred because the mass term of the equation was nearly zero, making the input torque nearly zero, and less than the very low 1.3Ncm resistance torque.

## **B. Ignition System Basics**

In order for a driver to easily operate the ignition key, the lock cylinder it fits into must be in an easily accessible position with his or her hand. The most common location for the ignition system is mounted to the steering column, but mounting positions such as the dashboard and the center console are sometimes used.

## **C. Development and Application of Unintended Key Rotation Tests**

I gained a broad understanding of automotive systems through my previous assignments and personal experience. I also possess knowledge of the Milford Proving Ground road system, familiarity with lab equipment, and understanding of computer aided analysis techniques. In February of 2014, my supervisor contacted me to support investigation of inadvertent transition of ignition state. I was given latitude to assemble a team, and personally selected the engineers supporting this project. The core team members were myself, Valarie Boatman (test engineer), John Boyer (test engineer), John Carriere (vehicle dynamics expert), Daniel Fosmer (measurement

expert), Jacob Gannon (test engineer), Ali Seyam (test engineer), and Peter Shear (measurement/instrumentation technician). The team was one of the best I have ever worked with and I am proud of its accomplishments.

The GM Milford Proving Ground was the industry's first dedicated automobile testing facility when it opened in 1924, and remains one of the most advanced. The facility covers about 6 square miles and has approximately 150 miles of roads designed to replicate the events vehicles can experience over the course their life. In addition to the road surfaces, the Milford Proving Ground is home to hundreds of advanced labs and simulation systems.



**Figure 1: Aerial View of Milford Proving Ground**

The team was given access to test facilities within the grounds and utilized several laboratories (4 post shaker, railway simulator, shipping simulator, hyge sled) as well as the road systems to develop unintended key rotation tests.





**Figure 2: Image of Four-Post Shaker**



**Figure 3: Image of Railway Simulator**





**Figure 4: Image of Shipping Simulator**

After hundreds of experimental tests utilizing multiple tests facilities, labs, and road surfaces, the team developed a repeatable method to evaluate robustness to unintended key rotation. The team formalized a subset of the experimental procedures into an unintended key rotation test procedure.

Due to the interactions between the factors that determine both the input torque and resistance torque, full vehicle tests were required to assess the robustness of the system to unintended rotation. Test results showed systems interactions had a significant effect on both the input acceleration – (different vehicles encountering the surface had different acceleration response in the vicinity of the ignition key due to many complex interactions and dynamic motions that occur between the tire encountering the surface and the steering column accelerating) and the system resistance torque. (Gear train, column locks, and other moving parts that had different designs across different vehicle lines contributed to the system torque) No singular parameter was sufficient to predict robustness to unintended key rotation.

The procedure utilized 8 driving events with specific items attached to the ignition key that checked for both inertial rotation as well as knee to key interaction and a test where the vehicle was stationary that checked for knee to key interaction. Vehicles were equipped with instrumentation to record the acceleration in the vicinity of the ignition key. If a rotation occurred, the drivers were instructed to note it in the run log. Multiple evaluators conducted the tests. The 8 driving events were selected to encompass the breadth of accelerations a vehicle would experience in both on and off road events without causing significant damage to the test vehicle. The non-driving test allowed evaluators encompassing a breadth of stature to focus on attempting to rotate the key with their knee without being distracted by the task of driving. A more detailed description of the test events is below.<sup>2</sup>

<sup>2</sup> The tests that the team developed to assess robustness to unintended key rotation are also described in several documents identified in Appendix B. See 2014\_05\_07 "Robustness to Unintended Ignition Key

## D. Description of Driving Tests

A more detailed description of each of the 8 driving tests is below:

**Ride & Handling Loop at Posted Speeds.** This test consisted of one lap in the right lane of the R&H Loop at posted speeds. The Ride and Handling loop is a 4-mile course that subjects the vehicle to significant longitudinal, lateral and vertical accelerations across a broad frequency spectrum.



Figure 5: R&H Loop Posted Speeds

Rotation with Key Ring Only" Presentation, J. Fedullo and A. Seyam; 2014\_05\_07 "Robustness to Unintended Ignition Key Rotation with Key Ring Only" Presentation, J. Fedullo and A. Seyam; 2014\_07\_17 "Summary of Vehicle Level Recall Verification Testing" Presentation, J. Fedullo; 2014\_07\_10 "Summary of Testing for Ignition Related Recalls (NHTSA 14V355 & NHTSA 14V400000)" Presentation, GM North America Engineering; 2014\_07\_14 "Ignition Switch Measurement Technical Assessment" Initial Overview Presentation, Virginia Tech Transportation Institute (VTTI); 2014\_08\_30 "Technical Assessment of Ignition Switch Test Methods, Procedures and Analysis Techniques" Report, Virginia Tech Transportation Institute (VTTI); 2016\_01\_08 GM Evaluation Report "On-Road and Static Evaluations of Ignition Switch," Valarie Boatman, Jacob Gannon, Ali Seyam and Peter Shear and Appendix D: Results Summary.





**Figure 6: R&H Loop Entrance.**

In the preceding image of the R&H loop, the chatter bumps are in the left lane. In the right lane are “waddles” — swells that are out of phase from left to right.



**Figure 7: “Bad Bump” on R&H Loop.**





**Figure 8: Damage on Roadway at Exit of “Bad Bump.”**

In the image preceding, note the damage on the roadway at the exit of the “bad bump,” which is shown previously. The roadway damage is due to contact with underside of vehicles exiting the “bad bump,” highlighting the severity of this driving event.



**Figure 9: “S curves” on R&H Loop.**

**Ride and Handling Chatter Bumps (45-55 mph).** This test consisted of entering the chatter bump portion of the left lane of the Ride and Handling loop at 55 mph and allowing the vehicle to coast until the end of the chatter bump section. Data indicated the speed at the end of the chatter bump section was consistently 45mph or less. The chatter bumps are a series of evenly spaced bumps roughly perpendicular to the direction of vehicle travel. The spacing of the bumps causes the first order input vertical and fore aft excitation frequency in Hz to be equal to the speed in mph divided by 3.



**Figure 10: Image of R&H Chatter Bumps.**



**Figure 11: Close-Up Image of R&H Chatter Bumps.**



**Ride and Handling Angled Rail Road Crossing (70mph).** Drivers were instructed to cross an elevated railroad crossing that is not perpendicular to the road direction at 70 mph minimum. This was in excess of the posted speed limit and required limit handling / high g certified drivers. This event inputs significant vertical acceleration, and video footage confirms the vehicle becomes partially airborne at the exit of this event (at least one wheel would lose contact with the ground)

As I discuss later in the report, an independent 3<sup>rd</sup> party, Virginia Tech Transportation Institute (VTTI), was contracted to perform a technical assessment of GM's ignition test methods, procedures and analysis techniques. VTTI visited the GM Milford proving ground and had access to the team working on robustness to unintended key rotation testing. As part of its assessment, VTTI instrumented multiple vehicles in the same manner as participants who participated in a naturalistic driving study — the second Strategic Highway Research Program (SHRP2) Naturalistic Driving Study (NDS). These instrumented vehicles were then subjected to the driving tests of the ignition test procedure at MPG. The MPG data was compared to data collected from the SHRP2 naturalistic driving study.<sup>3</sup> The SHRP2 NDS database comprises data from 35 million miles collected from 3,000 participant vehicles, including acceleration data, recorded at 10 Hz, from more than 1.2 million trips totaling more than 9 billion data points.<sup>4</sup>

As shown in Figures 60 through 62 of the VTTI Technical Assessment report, the acceleration content in all three directions (*i.e.*, longitudinal, lateral, and vertical) for each of vehicles tested on the ride and handling loop exceeded that of the on-road SHRP2 NDS data. VTTI also made an acceleration comparison between 312 off-road crash and near-crash events recorded in the SHRP 2 NDS database and the GM MPG events.<sup>5</sup> The off-road events recorded in the SHRP 2 NDS database included driving off road, over curbs, and driving into the median. Figures 69 through 71 of the VTTI Technical Assessment report show a comparison between the GM MPG Ride and Handling Loop events and the SHRP 2 off-road data, and there is comparable acceleration content between the data sets.

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<sup>3</sup> 2014\_08\_30 "Technical Assessment of Ignition Switch Test Methods, Procedures and Analysis Techniques" Report, Virginia Tech Transportation Institute (VTTI), at GM-MDL2543-301432457.

<sup>4</sup> 2014\_08\_30 "Technical Assessment of Ignition Switch Test Methods, Procedures and Analysis Techniques" Report, Virginia Tech Transportation Institute (VTTI), at GM-MDL2543-301432522.

<sup>5</sup> 2014\_08\_30 "Technical Assessment of Ignition Switch Test Methods, Procedures and Analysis Techniques" Report, Virginia Tech Transportation Institute (VTTI), at GM-MDL2543-301432535-38.





**Figure 12: Image of R&H Railroad Crossing.**



**Figure 13: Image of Vehicle Experiencing R&H Railroad Crossing.**

**Belgian Blocks RLDA Schedule.** This test consisted of completing a 1.7 mile loop paved with granite blocks. This test provides significant vertical and fore aft acceleration, both at high frequency due to individual blocks and low frequency due to the macro surface dips and bumps. This surface is normally used for accelerated durability testing and is not intended to duplicate normal “on road” conditions.

As shown in Figures 57 through 59 of the VTTI Technical Assessment report, the levels of acceleration throughout the entire cumulative percentage range in all three directions (*i.e.*, longitudinal, lateral, and vertical), are greater for the six tested vehicles on the Belgian blocks than the acceleration levels found in the SHRP 2 NDS database for on road events. Figures 66 through Figure 68 of the VTTI report show a comparison for all three accelerations (*i.e.*, longitudinal,

lateral, and vertical) to the Belgian Block MPG event. The GM MPG Belgian Block acceleration content exceeds the acceleration content of the SHRP 2 off-road data in all directions.<sup>6</sup>



**Figure 14: Belgian Block Road Surface (note large dip in road on left side).**



**Figure 15: Image of Belgian Block Road Surface.**

<sup>6</sup> 2014\_08\_30 "Technical Assessment of Ignition Switch Test Methods, Procedures and Analysis Techniques" Report, Virginia Tech Transportation Institute (VTTI), at GM-MDL2543-301432543-46.





**Figure 16: Close-Up Image of Belgian Block Road Surface (quarter in picture for scale).**

**Pothole No. 1 (25 mph).** Pothole No. 1 is a steel pothole set in concrete approximately 4 inches deep and 7.5 feet long. It is designed to subject the vehicle to extreme fore aft and vertical accelerations. Based on GM product usage data / measurements encountering Pothole #1 at 25 mph inputs a vertical acceleration of magnitude greater than half the population of vehicles will ever encounter during an entire vehicle life.



**Figure 17: Image of Pothole No. 1 (quarter in picture for scale)**

**Pothole No. 2 (25 mph).** Pothole No. 2 is a steel pothole set in concrete approximately 5 inches deep and 7 feet long. It is designed to subject the vehicle to extreme fore aft and vertical accelerations. Based on GM product usage data / measurements, encountering Pothole No. 2 at 25 mph inputs a vertical acceleration greater than 8 out of 10 vehicles will ever encounter during an entire vehicle life.





**Figure 18: Image of Pothole No. 2 (quarter in picture for scale).**

**Panic Stop (10–15 mph).** This test consisted of aggressive stops conducted on a smooth and level surface. The test procedure consisted of light acceleration to speeds of 10 to 15 mph, followed by a full and rapid brake pedal application. This was repeated 3 times. This test provides significant Fore Aft acceleration input.

A comparison to the SHRP 2 NDS data shows that the acceleration content for each of the six vehicles tested across Potholes #1 and #2 and the Panic Stop events exceeds the acceleration content reported in the SHRP 2 NDS database for on road events. Figures 72 through Figure 74 of the VTTI report show although there are portions of the plot where the SHRP 2 off-road data include more acceleration content than the GM MPG event these three GM MPG events provide greater acceleration input overall compared to the SHRP 2 off-road data.<sup>7</sup>

**Cubilete (10 mph).** Cubilete is a replica of a severe surface in Mexico. It is made up of rocks and boulders held in place with concrete. This test provides significant vertical and fore aft acceleration both at high frequency due to hitting individual rocks and low frequency due to the macro dips and bumps. This surface is normally used to assess anomalous steering system noises and not intended to duplicate “on road” conditions.

<sup>7</sup> 2014\_08\_30 "Technical Assessment of Ignition Switch Test Methods, Procedures and Analysis Techniques" Report, Virginia Tech Transportation Institute (VTTI), at GM-MDL2543-301432551-54.

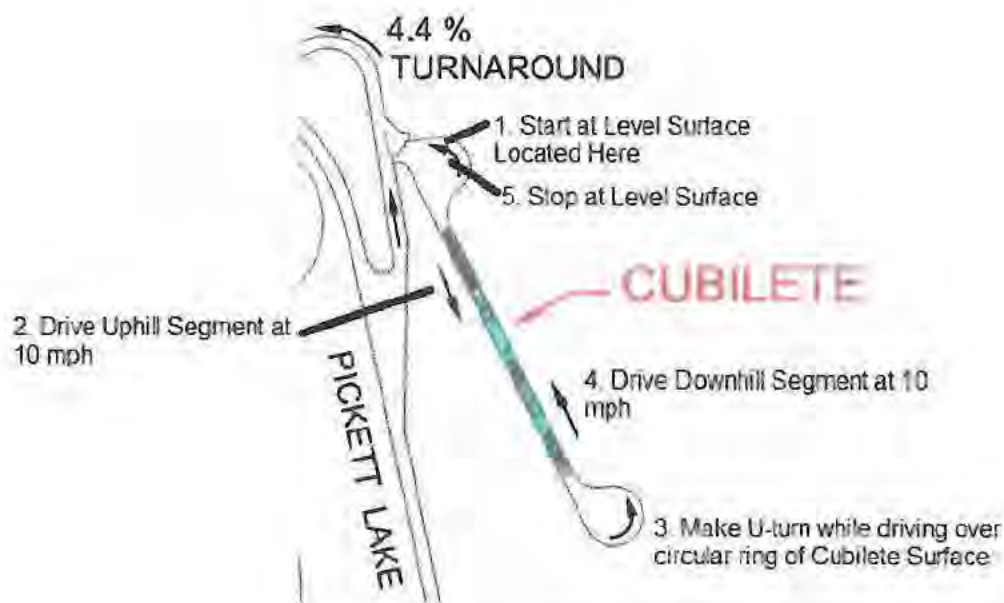


**Figure 19: Image of Cubilete.**



**Figure 20: Close Up Image of Cubilete Surface.**





**Figure 21: Cubilete Drive Schedule**

A comparison of the acceleration data of all 8 MPG driving events discussed above to the acceleration data from the SHRP2 database, including 312 off-road events, such as driving off road, over curbs, and driving into the medians, shows that the sum of the MPG driving events capture and exceed all accelerations recorded in the SHRP2 database.<sup>8</sup> This is not surprising as the MPG driving events were designed to encompass customer use and abuse events.

#### **E. Key Chain Study**

GM conducted an external mall intercept study at 4 malls within the United States (Boston, MA; Chicago, IL; Dallas, TX; Portland, OR) to determine the weight of customer keychains.<sup>9</sup> The population sample size was 502, and the average weight was 0.18 lbs. The maximum observed weight was 0.61 lbs. Statistical analysis of the data indicates 95 out of 100 people have key chains that weigh less than 0.35lbs. VTTI performed a similar study on campus with 60 participants and had similar results.<sup>10</sup> Their observed average was 0.23lbs and maximum was 0.5 lb.

<sup>8</sup> 2014\_08\_30 "Technical Assessment of Ignition Switch Test Methods, Procedures and Analysis Techniques" Report, Virginia Tech Transportation Institute (VTTI), at GM-MDL2543-301432522-55. VTTI reached the same conclusion: "Overall, comparing the GM MPG events to both the SHRP-2 on-road data and low-speed, off-road data showed that the GM MPG events capture and exceed the acceleration content seen in SHRP-2 NDS events." *See id.* at GM-MDL2543-301432555.

<sup>9</sup> 2014\_07\_17 "Summary of Vehicle Level Recall Verification Testing" Presentation, J. Fedullo, at GM-MDL2543-300899120-21.

<sup>10</sup> 2014\_08\_30 "Technical Assessment of Ignition Switch Test Methods, Procedures and Analysis Techniques" Report, Virginia Tech Transportation Institute (VTTI), at GM-MDL2543-301432460-61.





**Figure 22: Image of Keys Weighing 0.7lbs.**



**Figure 23: 0.7 lbs of Keys Attached to Ignition Key.**

The MPG driving test events exceed the acceleration inputs to the vehicle and driver during on and off road driving and replicate the most extreme dynamic conditions possible without

significant vehicle damage.<sup>11</sup> Although non deformable material such as asphalt, granite, cement, and rock were used to maintain their shape integrity with repeated use, the surfaces create input accelerations encompassing off road driving.

In addition to subjecting the vehicles and occupants to extreme acceleration, 0.7 lb. of mass attached to the key. This value is not only greater than the highest mass observed in the key chain mall intercept (0.61 lb.), it is double the mass attached to the ignition key of a 95<sup>th</sup> percentile customer (0.35 lb.) and almost four times the mass an average customer mass has attached to their keychain.(0.18 lb.)<sup>12</sup> Recalling the combination of the torque equation and Newton's law  $T = m \times a \times d$ , an increase in mass has the same effect on input torque as a proportionally equivalent increase in acceleration. For example, using a mass that is almost four times the average mass a customer has attached to their key ring would be the equivalent of a customer with an average mass attached to their keyring experiencing almost four times the acceleration experienced during the test. The accelerations experienced during the test have already been shown to exceed on and off road driving, and almost quadrupling the effect adds significant conservatism to the test.

#### F. Stationary Vehicle Testing

During the MPG driving tests, drivers were told to document inadvertent key rotation caused by any mechanism. Driving through the various events called for drivers to manipulate vehicle controls (e.g., moving their foot from accelerator to brake pedal, slamming on the brakes, etc...) and imparted forces on the driver's body that would cause it to move. Thus, if these intentional movements, or the driver's movements from forces being exerted on it, caused an inadvertent key rotation, it would have been reported and documented.

In addition to the driving evaluations, evaluations of the robustness to unintended driver interaction were done with the vehicle stationary.<sup>13</sup> By eliminating the distraction of the driving task, the evaluators were able to concentrate all of their efforts on trying to rotate the ignition key with their knee. These tests augmented the previously discussed driving tests.

Evaluators representing a breadth of driver statures were utilized for the stationary vehicle tests. A minimum of three evaluators were used meeting the following criteria, a female whose standing height was in the 5<sup>th</sup> percentile maximum, a male whose standing height was between 45<sup>th</sup> and 55<sup>th</sup> percentile, and a male with a minimum 95<sup>th</sup> percentile standing height. This stature range is consistent with GM established practices for visibility, operability, and restraints.

<sup>11</sup> 2014\_08\_30 "Technical Assessment of Ignition Switch Test Methods, Procedures and Analysis Techniques" Report, Virginia Tech Transportation Institute (VTI), at GM-MDL2543-301432522-55.

<sup>12</sup> 2014\_07\_10 "Summary of Testing for Ignition Related Recalls (NHTSA 14V355 & NHTSA 14V400000)" Presentation, GM North America Engineering, at GM-MDL2543-300899120-24.

<sup>13</sup> 2014\_07\_10 "Summary of Testing for Ignition Related Recalls (NHTSA 14V355 & NHTSA 14V400000)" Presentation, GM North America Engineering; 2014\_07\_29 "Gen 2 Cadillac CTS Knee Key - Recall Fix Evaluation" Presentation, GM Systems Engineering Field Response Team.



Each evaluator performed two categories of tests, normal driving positions and abnormal driving positions. For testing in normal driving position, the evaluator was instructed to sit in a normal driving position and evaluate the risk of the driver's knee contacting the ignition key causing unintended change to vehicle power mode. Drivers were instructed that movements to be evaluated should include any normal driving motions while in a vehicle. Examples include, but are not limited to, the following:

- Moving right foot from gas to brake pedals, both slowly and quickly
- Moving right foot from brake to gas pedals, both slowly and quickly
- Use of the clutch pedal with left foot
- Panic brake stops
- Feet pulled back in relaxed position to replicate use of cruise control
- Twisting to look back over each shoulder

The evaluators were also asked to deliberately try to change the vehicle power mode with their knee through any means, including motions that would not occur in a normal driving scenario, classified as abnormal driving positions. When instructing evaluators to perform the "abnormal" portion of the test I asked, "If someone offered a million dollars to rotate the ignition key with your knee, could you do it?" The test was not intended to duplicate an actual event, but to understand what extreme position an occupant would need to assume in order to rotate the key with their knee. Over the course of the abnormal testing, multiple ignition keys were broken due to the excessive force the evaluators applied.



**Figure 24: Breadth of Stature of Evaluators**

**G. Third Party Assessment**

As discussed previously, an independent third-party organization, VTTI, was contracted to perform a technical assessment of GM's ignition test methods, procedures and analysis techniques.<sup>14</sup> An excerpt from VTTI's report of the conclusions that it reached, where it determined that all tests were acceptable for existing vehicles, is shown below:<sup>15</sup>

## CONCLUSIONS AND SUGGESTED FOLLOW-ON PROJECTS

During its evaluation of the GM ignition switch tests, VTTI determined the following:

1. Inertial tests conducted at the GM MPG are robust and valid in determining scenarios during which inertial effects could rotate the ignition switch out of the "Run" position.
  - These tests will uncover the majority of inertial-based issues.
  - The tests appear to have a relatively low miss/false alarm rate (i.e., GM is finding what needs to be found during its inertial testing).
2. MPG testing could be reduced or even potentially eliminated if a large enough database of static models is created to robustly determine inertial effects.
3. The GM knee-key test, although somewhat subjective, is acceptable for examining this risk within existing vehicles.
  - However, enhancements are recommended to standardize the knee-key test process and quantify/improve results for future testing.
  - The potential exists to incorporate knee-key criteria into the current ergonomic design model at GM, further reducing future vehicle design issues relative to ignition switches.

In the same report, VTTI further concluded:<sup>16</sup>

In summary, VTTI found through its independent analyses that, overall, GM engineers have made significant progress in creating a robust series of tests that have already

performed well and will continue to perform as constructed. That is, GM is using a series of tests that will determine the likelihood of ignition switch issues, thus allowing for countermeasures to be developed for current vehicles, with the ultimate goal of implementing and enhancing these tests in future vehicle models to design out any ignition switch issues before they occur.

<sup>14</sup> 2014\_08\_30 "Technical Assessment of Ignition Switch Test Methods, Procedures and Analysis Techniques" Report, Virginia Tech Transportation Institute (VTTI), at GM-MDL2543-301432451-52.

<sup>15</sup> 2014\_08\_30 "Technical Assessment of Ignition Switch Test Methods, Procedures and Analysis Techniques" Report, Virginia Tech Transportation Institute (VTTI), at GM-MDL2543-301432610.

<sup>16</sup> 2014\_08\_30 "Technical Assessment of Ignition Switch Test Methods, Procedures and Analysis Techniques" Report, Virginia Tech Transportation Institute (VTTI), at GM-MDL2543-301432610-11.



## H. Application of Testing

The unintended rotation tests were effective at quantifying the robustness of a product to unintended key rotation. They were not only applied prior to recall decisions, but also used to validate the effectiveness of proposed recall remedies. In all cases, recall remedies were validated to be robust to unintended key rotation due to inertial and driver knee interaction. Although GM recommends only attaching a few essential objects to the keyring post recall, all recall remedies were validated to be robust to unintended key rotation with 0.7lb of keys (approximately 40 house keys) attached to the key ring.<sup>17</sup> The tests were also proactively applied to what at the time were future products. In 2014, the team performed the testing listed above on all 2014–2016 model year domestic vehicles.

## I. Observations Relative to Interactions

Review of the test results show no single attribute or variable was sufficient to predict robustness to unintended key rotation.<sup>18</sup>

From an inertial perspective, unintended rotation occurs when the input torque exceeds the resistance torque. The resistance torque is the total torque required to rotate the key which depends on the resistance provided by all the moving components between the key and the switch. Items that affect the system torque other than the ignition switch are, the lock cylinder torque, the gear train torque if gear driven, the friction of a column or park interlock if equipped, etc. Different vehicle architectures have different combinations of the aforementioned components and therefore have different effects on system torque. Test data showed even quantification of the total system resistance torque is insufficient to predict robustness to unintended key rotation.

The input torque also varies considerably not only based on the mass attached to the key, but also due to the length of the hole in the key head, and the acceleration response of the vehicle when encountering surfaces. Suspension topology and wheel size are among the parameters that will cause different vehicle acceleration levels when different vehicles encounter the same bump. Consider a stiff sports car and a plush sedan hitting a small bump, the resulting acceleration the driver and the vehicle body sees in the plush sedan will not be nearly as noticeable as in a stiff sports car. In addition to differences in vehicle level response to the same input, there are also differences driven by the distribution of stiffness and damping in-between the suspension attachments and the vicinity of the ignition lock cylinders.

<sup>17</sup> 2016\_01\_08 GM Evaluation Report "On-Road and Static Evaluations of Ignition Switch," Valarie Boatman, Jacob Gannon, Ali Seyam and Peter Shear (Appendix D: Results Summary).

<sup>18</sup> 2014\_04\_28 "Unintended Ignition Switch Rotation" Presentation, J. Fedullo, at GM-MDL2543-300894235-52.



Interaction with the driver's knee also is not dependent upon a single variable.<sup>19</sup> The test data shows interaction is dependent upon multiple variables, including the proximity of the knee to the key, the angle of the key head and the angle of the leg when seated.

Due to system interactions discussed above, full vehicle tests were required to assess robustness to unintended key rotation.

## **J. Recall Remedies Vary**

Because the root cause for the recall conditions varied, the remedies also varied. Design for Six Sigma (DFSS) techniques were used to determine the best method of increasing robustness to unintended key rotation.<sup>20</sup> DFSS is an internationally accepted process for product design used across many industries including, but not limited to automotive, aerospace, home appliances, heavy equipment, & electronics. It is focused on evidence / data based decision making. One of the main goals is improved performance across a wide range of uncontrolled operating conditions. (Noise)

Application of the DFSS techniques summarized in Figure 25 indicated the most effective way to increase robustness to unintended inertial rotations was achieved via a design change to the ignition key head reducing the length of the slot which the key ring attaches. This significantly reduced / practically eliminated the moment arm for the input forces. Without a moment arm, a torque cannot be generated, and without a torque, the key will not rotate.<sup>21</sup>

In all driving testing of keys with a 4mm hole or 4x6mm slot, (100s of tests) key rotation was never observed regardless of ignition system torque.<sup>22</sup> This included tests when over 3 lbs (equivalent of 177 house keys) was attached to the key ring.<sup>23</sup> 1<sup>st</sup> principles, DFSS analysis and

<sup>19</sup> 2014\_04\_28 "Unintended Ignition Switch Rotation" Presentation, J. Fedullo, at GM-MDL2543-300894235-52.

<sup>20</sup> 2014\_04\_28 "Unintended Ignition Switch Rotation" Presentation, J. Fedullo, at GM-MDL2543-300894235-52.

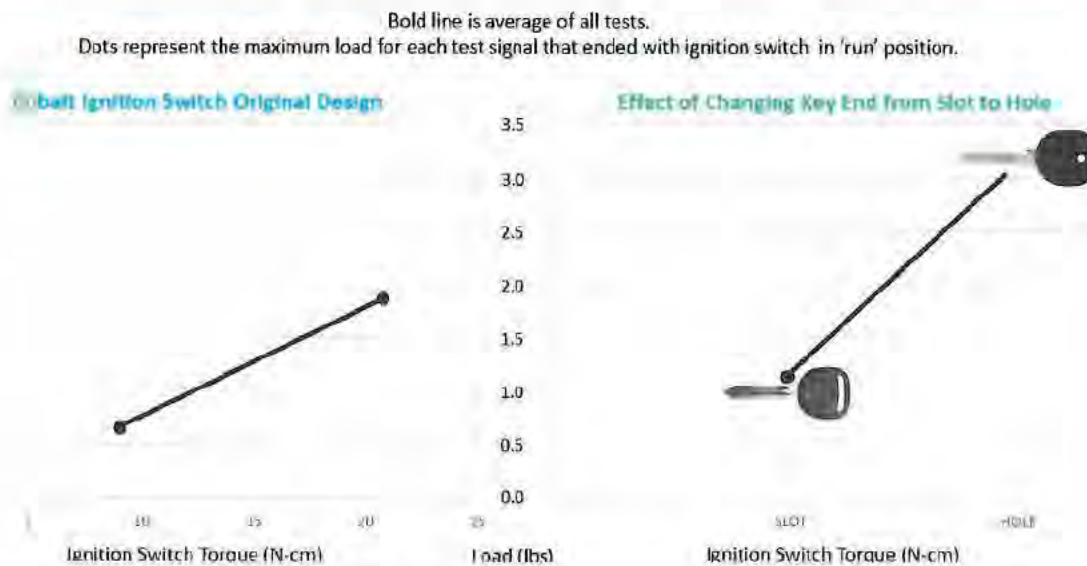
<sup>21</sup> 2014\_07\_10 "Summary of Testing for Ignition Related Recalls (NHTSA 14V355 & NHTSA 14V400000)" Presentation, GM North America Engineering, at GM-MDL2543-300899122-23; 2014\_05\_07 "Robustness to Unintended Key Rotation with Key Ring Only" Presentation, J. Fedullo and A. Seyam, at GM-MDL2543-300894761; 2014\_04\_28 "Unintended Ignition Switch Rotation" Presentation, J. Fedullo, at GM-MDL2543-300894235-52.

<sup>22</sup> 2014\_04\_03 GMNA Road Load Data Acquisition Workbook, GM-MDL2543-001227881-8048; 2016\_01\_08 GM Evaluation Report "On-Road and Static Evaluations of Ignition Switch," Valarie Boatman, Jacob Gannon, Ali Seyam and Peter Shear (Appendix D: Results Summary).

<sup>23</sup> See, e.g., 2014\_04\_03 GMNA Road Load Data Acquisition Workbook, at GM-MDL2543-001228020-021.



test data all confirm the practical elimination of the moment arm is by far the most effective design change to improve robustness to unintended inertial key rotations due to inertial affects.



**Figure 25: Relative Effect of switch torque vs Key Design Change**



**Figure 26: 3.1lbs Attached to Ignition Key**

Recall remedies to increase robustness to unintended key rotation due to driver knee interaction varied depending on the system interactions. For instance, on the Zeta platform (Camaro, G8, Caprice) the forward edge of the key head was lower than the rearward edge (at a position in-between 4 and 5 o'clock) when the ignition was in the run position.<sup>24</sup> If the driver lifted their knee and contacted the ignition key, initial contact would be at the forward edge of the

<sup>24</sup> See, e.g., 2014\_06\_19 "Camaro Ignition Studies" Presentation, V. Boatman, at GM-MDL2543-300897783-84.

key. Pushing up on the forward edge produces a counter clockwise moment when looking down the key axis which tends to rotate the key away from Run and towards ACC / Off. The Camaro recall remedy included a new ignition key that rotated the key head 90 degrees relative to the key blade.<sup>25</sup> This rotates the key head when in the run position such that the forward edge of the key head is now in-between the 1 and 2 o'clock positions and makes the rearward edge the lowest point. By having the rearward edge lower than the forward edge of the key, pushing up creates a clockwise moment on the key which is resisted by the crank spring and does not change the vehicle power mode.<sup>26</sup>



**Figure 27: Image of 2012 Chevrolet Camaro Key Angle**

In general, interaction that caused unintended rotation occurred when the driver's knee was observed to move up, up and forward, or up and lateral. When a driver moves their knee down, it tends to move away from the ignition key. To increase robustness to unintended ignition key rotation due to the contact with items hanging from the keyring a design change was made to the keyring. The single 25mm keyring was replaced with two 13mm key rings. A single keyring has the ability to transmit upward force into the forward edge of the key head once the slack in the key head is taken up. Changing the design from a single large keyring into two smaller links significantly reduced the ability of objects attached to the key to transmit upward forces to the ignition key. The two small key rings behave similar to the links of a chain and do not allow an upward force to be transmitted through the links. Much like pushing on a rope does not provide useful force transmission, pushing on a chain or a pair of keyrings behaving like the links of a chain breaks up the ability of the objects attached to the rings to provide an upward force

<sup>25</sup> 2014\_06\_11 "Unintended Ignition Key Rotation - 2010-2014 Chevrolet Camaro" Presentation, at GM-MDL2543-301823436; 2014\_06\_19 "Camaro Ignition Studies" Presentation, V. Boatman, GM-MDL2543-300897782-810.

<sup>26</sup> 2014\_06\_11 "Unintended Ignition Key Rotation - 2010-2014 Chevrolet Camaro" Presentation, at GM-MDL2543-301823436; 2014\_06\_19 "Camaro Ignition Studies" Presentation, V. Boatman, GM-MDL2543-300897782-810.



## **K. Reporting and Documentation**

Consistent with sound engineering principles, the engineering reports and presentations listed in Appendix A document the test procedures, instrumentation, and results in significant detail.

## **VI. OPINIONS**

### **A. GM Applied Sound Engineering Judgment to Develop Robustness to Unintended Key Rotation Assessment Testing.**

GM assembled team of engineering test and evaluation experts that developed a procedure to assess robustness to unintended key rotation. They experimented with multiple testing techniques and procedures prior to formalizing the unintended key rotation procedure. The procedure encompassed on and off road acceleration levels as confirmed by VTTI's comparison to the SHRP2 naturalistic driving study. Further conservatism was provided by setting mass attached to the key to pass the test at twice what a 95<sup>th</sup> percentile customer used and greater than any value observed in clinic data. The knee key tests performed when the vehicle was stationary utilized a breadth of evaluators with standing heights spanning from a 5<sup>th</sup> percentile female to a 95<sup>th</sup> percentile male, consistent with established practices for visibility, operability, and restraints. In addition to internal review, the test procedures were assessed by an independent 3<sup>rd</sup> party, VTTI, and all were found to be acceptable or conservative to the point of finding false positives.

GM utilized a well-qualified team, established engineering procedures, conservative methods, and internal & external peer reviews, to develop and document the unintended key rotation procedures. This supports my opinion that GM applied sound engineering judgment to develop robustness to unintended key rotation assessment testing.

### **B. GM Applied Sound Engineering Judgment in Conducting the Robustness to Unintended Key Rotation Assessment Testing for Vehicles Subject to the Investigations That Resulted in Each of These Recalls.**

Driving tests were performed on engineered surfaces designed to maintain their shape profile when subject to extreme loads. Drivers were certified to operate vehicles at the limits of their handling capabilities. Selection of appropriate instrumentation, sampling rates, and other setup details was overseen by trained measurement engineers. Measurement and data collection devices were calibrated. Logs of data collected, instrumentation used, and vehicle setup were kept. The data collection and the test procedures were documented in engineering reports that were peer reviewed prior to internal publication.

When available, the more conservative approach was used. For example, if multiple examples of a vehicle architecture were available, the one with the lowest measured switch torque was always included in the testing. If ratings differed between evaluators, all ratings were collected and published.

GM utilized repeatable and verified tests in a controlled facility with trained measurement engineers, certified drivers, and calibrated instrumentation. The results were documented in a

manner consistent with GM engineering practices and the reports were peer reviewed. This supports my opinion that GM applied sound engineering judgment in conducting the robustness to unintended key rotation assessment testing for vehicles subject to the investigations that resulted in each of these recalls.

**C. GM Applied Sound Engineering Judgment in Developing and Conducting the Tests to Assess the Recall Fix for Each of These Recalls.**

The same tests were used to assess the recall fix for unintended key rotation as those described earlier. These test procedures were assessed by an independent 3<sup>rd</sup> party VTTI and all were found to be acceptable or conservative to the point of finding false positives. For the reasons stated previously, my opinion is that GM applied sound engineering judgment in developing and conducting the tests to assess the recall fix for each of these recalls.

**D. The Remedies for Each of These Recalls Sufficiently Address the Recall Condition from an Engineering Standpoint.**

First principles/physics, test data, and DFSS analysis support the design changes implemented with the recall remedies. Changing from a large slot to a small hole in the key to practically eliminate the input moment a hanging mass can produce. This was confirmed via testing (After over a hundred tests on various vehicles, an inadvertent key rotation never occurred on any driving test when a key with a hole or 4x6mm slot was utilized) and DFSS analysis indicated the key head change was the most robust design change.

The physics based hypothesis that utilization of multiple key chains practically eliminate the ability of items attached to the key ring to generate an upward force (you can't push on a rope) was confirmed via testing and shown to effectively mitigate unintended rotation where applied. Physics based hypotheses that the design changes to key head orientation on the Zeta platform should reverse the direction of the torque applied to the key by the driver's knee moving upward was confirmed via testing.

The recall solutions were based on first principles and all were confirmed to be effective at mitigating unintended key rotation via validated testing. This supports my opinion that the remedies for each of these recalls sufficiently address the recall condition from an engineering standpoint.



## VII. CONCLUSION

I have reached the opinions disclosed in this report to a reasonable degree of engineering certainty based on information known to me and that has been made available at this time. I reserve the right to amend or supplement any and all of these opinions should I receive new information.



Joseph Fedullo

**Appendix A**

<b>Tab No.</b>	<b>Reliance Material</b>	<b>Bates Number</b>
1	2014_05_06 "Robustness to Unintended Key Rotation with Key Ring Only" Presentation, J. Fedullo and A. Seyam (publically available on NHTSA website)	
2	2014_05_07 "Robustness to Unintended Ignition Key Rotation with Key Ring Only" Presentation, J. Fedullo and A. Seyam	
3	2014_05_06 Letter From Secretary of Transportation Anthony R. Foxx to Senator Edward J. Markey	GM-MDL2543-300894759
4	2014_04_28 "Unintended Ignition Switch Rotation" Presentation, J. Fedullo	GM-MDL2543-300894235-52
5	2014_07_17 "Summary of Vehicle Level Recall Verification Testing" Presentation, J. Fedullo	GM-MDL2543-200120637-42
6	2014_06_19 "Camaro Ignition Studies" Presentation, V. Boatman	GM-MDL2543-300897782-810
7	2014_06_11 "Unintended Ignition Key Rotation - 2010-2014 Chevrolet Camaro" Presentation	GM-MDL2543-301823423-43
8	2014_07_10 "Summary of Testing for Ignition Related Recalls (NHTSA 14V355 & NHTSA 14V400000)" Presentation, GM North America Engineering	GM-MDL2543-300899117-47
9	"Unintended Ignition Switch Rotation - Models (K/H/8E/M, MS-2000, & U-van platforms" Presentation	GM-MDL2543-301837946-90
10	2014_07_29 "Gen 2 Cadillac CTS Knee Key - Recall Fix Evaluation" Presentation, GM Systems Engineering Field Response Team	GM-MDL2543-301529716-21
11	"Unintended Ignition Key Rotation - 2003-2014 Cadillac CTS and 2004-2009 Cadillac SRX" Presentation	GM-MDL2543-400294523-46
12	2014_07_14 "Ignition Switch Measurement Technical Assessment" Initial Overview Presentation, Virginia Tech Transportation Institute (VTTI)	GM-MDL2543-300899208-30
13	2014_08_30 "Technical Assessment of Ignition Switch Test Methods, Procedures and Analysis Techniques" Report, Virginia Tech Transportation Institute (VTTI)	GM-MDL2543-301432431-653
14	2014_04_03 GMNA Road Load Data Acquisition Workbook (Excerpted)	GM-MDL2543-001227881-8048
15	Figure A1: Vehicles Evaluated Spreadsheet (Sorted)	
16	2016_01_08 GM Evaluation Report "On-Road and Static Evaluations of Ignition Switch," Valarie Boatman, Jacob Gannon, Ali Seyam and Peter Shear and Appendix D: Results Summary	GM-MDL2543-304953622
17	2014_04_28 GMNA Road Load Data Acquisition Report	GM-MDL2543-001241668



# APPENDIX B

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# Joseph S. Fedullo

Work: (248) 930-7219  
Joe.Fedullo@gm.com

## EMPLOYMENT:

- 6/14 – Present **GM - Vehicle & Propulsion Systems Engineering – Director** (Warren, MI)
- Formed Systems Engineering organization from ground up focused on safety & compliance
  - Responsible for Chassis, Fuel, Propulsion, and Occupant Protection domains
  - Defined organizational deliverables, staffing, training, metrics, and budget
  - Immediate organizational successes lead to a doubling of staffing from 70 to 140 engineers in 1 yr.
  - Develop and roll down Feature and System level requirements, FMEAs, and support investigations
  - Managed 15M budget
- 1/14 – 6/14 **GM - Pre Integration Vehicle & Road to Lab to Math groups – EGM** (Milford, MI)
- Simultaneously lead Pre Integration Vehicle team and established the Road to Lab to Math team with a total of 35 direct report engineers
  - Utilize CAE simulation & XIL to reduce dependency on physical vehicles
  - Reduced development time & vehicle count, while simultaneously increasing fidelity
  - Developed transient handling and steering metrics enabling tuning calibrations via HIL
  - Developed objective testing & criteria for unintended ignition rotation
- 6/13 – 1/14 **GM - Pre Integration Vehicle – Engineering Group Manager** (Milford, MI)
- Merged 2 groups into a team of 19 engineers responsible for Advanced Vehicle Dynamics development and HIL simulation
  - FMVSS 126 vehicle certifications completed using HIL alone
  - Developed ABS, ESC, and other chassis controls feature calibrations on HIL benches
  - Hired new engineers and established a team lead / mentor program for them
  - Increased usage of analytics (CarSim, SuspSim) in advanced vehicle dynamics
  - Cross trained “HIL” engineers with Advanced Technology chassis development projects
- 6/12 – 6/13 **GM - Advanced Vehicle Dynamics - Engineering Group Manager** (Milford, MI)
- Lead team of 12 engineers and technicians responsible for global vehicle dynamics development
  - Delivered balanced chassis solutions that met cost, mass, and durability targets via collaboration with suppliers, CAE, vehicle performance and release teams
  - Supported all vehicle dynamics Advanced Technical Work. Lead advanced development techniques and university projects enabling elimination of build phase
  - Responsible for team staffing, people growth, coaching, training and mentoring
  - Managed \$250,000 material / travel / maintenance budget
  - Implemented process improvements that increased quality and throughput by 25%
- 12/05 – 6/12 **GM – Advanced Vehicle Dynamics - Suspension Subject Matter Expert** (Milford, MI)
- Responsible for leading Engineering Development Vehicle (EDV) development, Advanced Technology Projects, and developing Core Chassis strategy
- EDV Development: Responsible for tuning all aspects of the chassis to determine architecture's capability to achieve stated performance requirements. Tuning includes spring rates, stabilizer bars, damper, jounce bumper, bushing rate, bushing type, spring isolators, I-shaft, HPS / EPS calibration
    - Omega: Identified critical jounce bumper parameters required to achieve ride target. Resulted in multiple jounce bumper strategy to manage loads and ride across several tire packages
    - Developed high bandwidth fully active suspension system. Uncovered fundamental issues, and cancelled project with minimal resource investment
    - Alpha: Developed chassis that achieved ride / handling targets and exceeded steering expectations. Developed new damper valving system improving ride verses handling balance
  - Advanced Technology Projects: Responsible for leading advanced chassis design projects
    - Integrated jounce shock: Integrated Light Racing jounce shock into a damper
    - High Velocity Damping: Developed loads mitigation strategy utilizing increased damping at extreme velocities. Demonstrated via analytical modeling and vehicle measurement
    - Decoupled 5-link: Developed new independent suspension concept for small car
    - Global Small Top mount development engineer for corporate common component
  - Chassis Fundamental Work
    - Developed teaching aids for suspension design and vehicle dynamics used to mentor GM China chassis engineers during weekly 1 on 1 meetings
    - Generated Global groundline test criteria to match CAD requirements
    - Led Global GM vehicle dynamics team to achieve agreement on suspension contenting tool
    - Weekly senior leadership “Knothole” rides. Responsible for logistics, identifying key vehicles, scheduling / renting / trading / preparing vehicles and determining routes based on mission.
    - Developed objective metric for lateral shuffle, and key suspension parameters to control it.

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- 7/00 – 12/05 **GM – Chassis Center - Lead Suspension Engineer** (Warren, MI)
- Lead suspension engineer responsible for suspension topology selection, layout geometry, and compliance balance. Constructed and ran Adams/MotionView & Unigraphics CAD models to optimize total vehicle performance & package. Lead engineer for:
    - Theta Epsilon front base / premium suspension (MacPherson / HiPerStrut): Co invented GM's HiPerStrut & critical revolute joint for this program
    - 2<sup>nd</sup> generation Sigma front and rear suspension (High arm SLA / 4.5 link): Significant improvement over first generation CTS front suspension. Industry first incorporation of a direct acting stabilizer bar on an SLA cancelling unwanted kingpin moments
    - Lambda Linked H-arm rear suspension: First GM application of this suspension topology, GM embodiment exhibits industry-leading ride.
    - Lambda Steerable IRS: Incorporation of novel mechanism that used center take off rack and pitman arms with a rear SLA
    - Lambda 5-link rear suspension: Package would not allow for proper damper orientation resulting in high levels of damping force induced steer. Concept abandoned for this platform
    - Midsize BOF SUV Dedion rear suspension/load floor suspension: Enabled driven rear axle with 100mm lower load floor without negatively impacting performance. (Program cancelled)
    - Theta SS/GT Rear suspension (4-link): Incorporated evolutionary changes to existing 4-link suspension with all new geometry and links. Replaced all rear suspension variants for Theta.
    - Theta ParadiGM front and rear suspension (Strut / 4-link): Concept vehicle
    - GMT001 (Delta) Front suspension (MacPherson Strut): Evolutionary change for increased caster angle and trail. Solution met all requirements via changes to only one component.
  - Tire Envelope Subject Matter Expert
- 6/98 – 6/00 **Lucent Technologies – Bell Labs Innovations** (Holmdel, NJ)
- Mechanical lifecycle support of Lucent 90XX Pocketphone handsets. Analyses of high-speed video to understand bending modes and corresponding interference between parts when dropped
  - Created Pro/E models for rapid prototyping of design changes. Improved performance resulted in \$800,000/yr savings
  - Mechanical design and release of Lucent Technologies 9631A wireless business phone
- 5/97 – 6/98 **Northrop Grumman Corp. – Advanced Systems and Technologies Dept.** (Bethpage, NY)
- Research internship to determine feasibility of double diaphragm forming of advanced composite materials as an alternative to hand lay-up processes used on military aircraft

**EDUCATION:** **The University of Michigan; Ann Arbor, Michigan**  
 Master of Engineering in Automotive Engineering - July 2000  
 Cumulative GPA: 3.9/4.0 Major GPA: 4.0/4.0  
 Teaching Assistant for ME 458 "Automotive Engineering" & ME 542 "Vehicle Dynamics"

**The Cooper Union for the Advancement of Science & Art; New York, NY**  
 Bachelor of Engineering in Mechanical Engineering - May 1998  
 Full tuition merit scholarship - Cumulative GPA: 3.5/4.0 Major GPA: 3.6/4.0,  
 Capstone Design Project: Chassis design of 1998 SAE Mini-Baja East vehicle

**HONORS AND ACTIVITIES:**

- Active member of SAE & INCOSE
- GM "Boss Kettering" award for HiPerStrut suspension design
- GM "Employee Excellence" award for work ignition recall related work
- Testified in Federal court on behalf of GM for ignition related cases
- US Patent US 9,308,793 B2 – "Multi-Density Jounce Bumper"
- Two Defensive publication (Utilization of RTD for passive damper tuning, HV damping)
- Co-Author SAE 2013-01-1357 "A Computational Method for Efficient Hub Offset Evaluations with Deflected-Disc Dampers"
- Two Lucent Technologies "President's Awards" (One for cost reduction, One for design)
- Moderated grad/undergrad engineering classes offered through GM (UofM - ME542, ME458, ME599V, Purdue - ME565, Michigan tech - MEEM2500)
- Pi Tau Sigma Honor Society for Mechanical Engineers

**COMPUTER:** MS Office Suite, ADAMS, Adobe, CarSim, MotionView, Pro/E, Unigraphics, Teamcenter

**SKILLS:** New York State licensed Intern Engineer  
 Project Management (DFSS Blackbelt, OpEX, GoFast, CPM) & ISO 9001/14001 trained  
 ISO 26262 Functional Safety - Automotive Safety Integrity Level (ASIL)  
 Car Nut

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Depositions						
1	9/11/2015	General Motors LLC Ignition Switch Litigation	N/A	United States District Court, Southern District of New York	14-MD-2543 (JMF)	400 Renaissance Center, Detroit MI
2	5/18/2017	People of the State of California v. General Motors, LLC	N/A	Superior Court of California, County of Orange	30-2014-00731038	211 West Fort Street, Detroit MI

Trial Testimony						
1	1/29/2016	General Motors LLC Ignition Switch Litigation	N/A	United States District Court, Southern District of New York	14-MD-2543 (JMF)	500 Pearl Street, New York, NY

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